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A Modular Software Shell for Life-Cycle Nuclear Survivability (LCNS) Data Acquisition and Management

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13. ABSTRACT *(Maximum 200 words)*

As part of the Army's Life-Cycle Nuclear Survivability (LCNS) program, a software package has been developed to provide turn-key LCNS data acquisition and statistical database operations for military systems. The modular design accommodates all existing test, measurement, and diagnostic equipment (TMDE) suites as well as those that may be operational in the future. With all LCNS test suites operating under this software, individual equipment needs are accommodated and all data are obtained in the same manner and format. Most of the logistical problems associated with monitoring life-cycle nuclear hardness are eliminated.

Most of the software operates as a program shell. System characteristics and requirements, test procedures, and instrument drivers are contained and accessed through external modules. To accommodate future changes, the program is designed so that only specific modules need to be rewritten, rather than entire software packages.

Although the program shell has an LCNS test "flavor," the software provides control for almost any type of testing. Additionally, there are generic test functions throughout the shell that enable the software to be used in a more flexible scenario for testing related to research and development.

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1. Introduction

The U.S. Army Harry Diamond Laboratories (HDL) has initiated an effort to develop a suite of mobile test, measurement, and diagnostic equipment (TMDE) for monitoring the life-cycle nuclear survivability (LCNS) of military systems. It is desirable to monitor these systems in the field instead of returning them to a depot; hence, a mobile LCNS TMDE suite is required. There is also a goal to standardize LCNS test procedures and logistics.

Total program efforts consist of the development and demonstration of a complete mobile TMDE suite. This includes all instrumentation, operating system hardware and software, and database functions necessary to collect and process LCNS data. The platform for the LCNS TMDE suite (identified through feasibility studies) is an S280 shelter, which puts several restrictions on the configuration of the suite because of its physical size. In consideration of these restrictions, we chose an operating system based on a personal computer (PC) to control the TMDE suite. Efforts to date have concentrated on the design and demonstration of the PC operating system/software and the ability to collect and manage LCNS data.

2. Modules

Without prior knowledge of the hardware to be controlled, we are posed with several obstacles in designing the actual operating system software. We thus developed and pursued the concept of a modular operating system as a viable solution to many of the problems that had been identified.

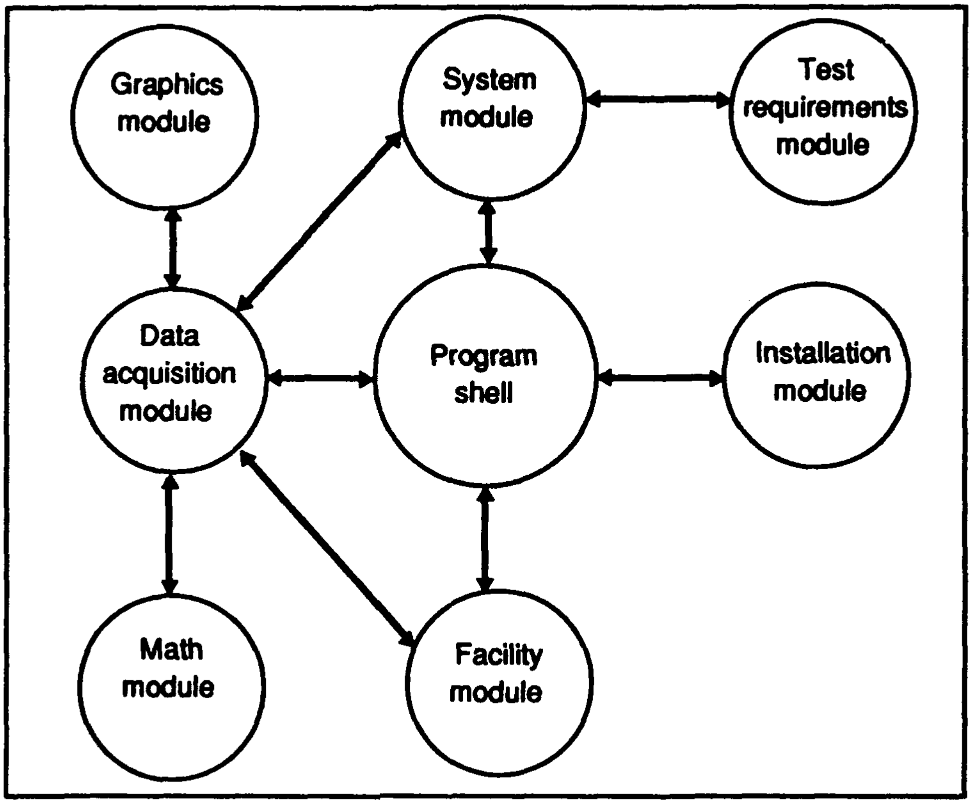
Characterizing this modular concept is a generic control shell, which is the foundation of the operating software, that loads specific information from external modules (see fig. 1 for a graphic representation of shell/module interaction). The entire software package can be developed without regard to the specific instrumentation or hardware, including the PC itself, that will ultimately make up the TMDE suite. Adding any given piece of hardware to the TMDE suite requires only the creation of a driver module; the entire software package need not be rewritten.

The inherent flexibility of this modular design allows for the addition of any instrumentation and hardware (current or future technologies). Similarly, changes to military standards (MIL-STDs) or system requirements can be incorporated into the software through modifications at the module level. The modular design is so flexible, in fact, that the system may be used for all types of testing in addition to LCNS testing.

2.1 Installation Module

The installation module is comprehensive in that it provides configuration management of the control software and the PC hardware. The installation

Figure 1. Modules/program shell interaction.



software is very similar to that found in commercial software packages and provides for printer/plotter support, directory/path creation, central processing unit (CPU) speed determination (for aesthetic purposes), and automatic detection of graphics/monitor capability.

2.2 Facility Module

Closely related to the installation module, the facility module provides configuration management of test instruments and data acquisition hardware. The facility module is very specific for each particular TMDE suite, and contains information on the suite's data links, sources, calibration files, sensors and probes, and any other test hardware.

From the facility module, you may select or configure complete end-to-end data links, check or perform calibrations, and substitute or add equipment (you must also supply a driver for each new instrument that is to be computer controlled*). Specific data links or hardware configurations may be configured, named, stored, calibrated, and later called up to provide immediate setup configurations or provide instrumentation histories to aid back-tracking/troubleshooting of previously measured data.

**The instrument drivers, as well as the calibration files, are actually contained within the data acquisition modules (see sect. 2.6).*

2.3 Graphics Module

The graphics module consists of a series of routines that allows you to produce graphic representations of the system under test, including an overlay of test-point locations. The graphics module can also plot and print data waveforms, as well as display existing graphics that may be provided by the test requirements module (see sect. 2.5). This visual aid greatly enhances test-point identification and provides real-time progress reports by displaying completed/uncompleted test points.

2.4 System Module

The system module is a highly interactive collection of system-specific descriptions and LCNS requirements for the particular system under test. It interacts with the data acquisition, test requirements, and graphics modules at test time. The information within this module contains the parameters that globally define the type and amount of testing to be conducted on the system. The module contains information for the following: MIL-STD and other test requirements, specific test points, special test procedures, expected data levels or baseline data, references to supporting manuals or graphic displays, and any special logistics.

2.5 Test Requirements (MIL-STD) Module

The test requirements module (a test-interactive module) identifies and defines the specific test to be performed. The actual data acquisition and instrument control modules* simply acquire generic data, but the test requirements module specifically defines and sets the parameters for each piece of data to be collected.

The test requirements module is actually a collective group of submodules. In many cases, particularly for LCNS testing, the test requirements are specified by a MIL-STD; therefore, the module contains "canned" MIL-STD submodules. Aside from MIL-STDs, the module contains several predefined "vanilla" submodules that define certain common or generic test types (e.g., shielding effectiveness, cable-fault location, insertion loss, etc). Furthermore, there is a vanilla submodule that is, more specifically, a "dummy" submodule. You may input to the dummy submodule any requirements you desire, therefore providing totally generic data acquisition for research and development or diagnostic testing.

2.6 Data Acquisition Modules

The data acquisition module is the heart of the run-time testing operation. Although it will access other modules for various information, the data acquisition module completely controls testing at the test-point level. All instrument drivers and calibration files are contained or accessed from

See section 2.6, Data Acquisition Modules.

within this module. If you attempt to use any device that either has not been calibrated or is out of calibration, the data acquisition module will warn you and suggest alternative instruments or allow real-time calibration of the instrument.

Based on the current test-point requirements, the data acquisition module will initialize itself into either a frequency domain testing mode or a time domain testing mode. Although the modes of operation are functionally very similar, having two different modes allows the module to initialize itself to inherently different test types and increase the efficiency of the data acquisition process.

2.6.1 *Frequency Domain Testing*

In the frequency domain mode of operation, the data acquisition module uses one or more network analyzers and spectrum analyzers* to measure the frequency response of one or more test points at a series of discrete frequencies. The module also controls any auxiliary equipment (such as amplifiers, fiber-optic links, probes, and sensors) in harmony with the analyzers and the data acquisition process.

Network analyzers provide their own source to "drive" the test point, and since the network analyzer can measure signals relative to a reference signal input, transfer functions may be measured. Spectrum analyzers may be mated with a tracking generator, in which case they essentially have their own source; or an external source can be selected and controlled. Although spectrum analyzers cannot reference the input in real time, references can be made with additional test shots. In any case, all instrumentation functions identically as far as the module is concerned; only the device drivers differ.

Once the raw data have been obtained, the module accesses the test requirements and system modules to obtain the data processing requirements and the baseline data or pass-fail specifications. The raw data are first processed and then compared to the baseline or pass/fail criteria. The baseline data and pass/fail criteria are comparison points for determining the integrity of the system for each test point. Baseline data may be either the original data collected during the verification/acceptance testing or the previously measured LCNS data. The pass/fail criteria form some parametric bound that defines the minimum specification a system must meet (such as a MIL-STD shielding effectiveness requirement). If serious discrepancies exist, the module may suggest several sanity checks (the integrity of calibration files, connectors, cables, etc) to ensure that valid data have been obtained.

**Other devices can also provide frequency domain measurements. Our discussion has been limited to those devices that are computer controlled and the most commonly used.*

2.6.2 *Time Domain Testing*

The function of the time domain mode is almost identical to the frequency domain mode except that in the time domain mode the module uses digitizers or oscilloscopes to measure the system response at one or more test points. In the time domain mode, the module expects an external source, use of timing/trigger devices, and a high degree of data processing. The digitizers measure the instantaneous response at successive time increments, thus recording a discrete (digital) time domain waveform. The data may then be processed and compared to previous measurements, as was the case for the frequency domain mode.

2.7 Math Module

The math module is simply a collection of canned data processing routines. These routines are accessed by the data acquisition module for processing raw data. The data acquisition module can access mathematical operations necessary to "scale out" instrumentation effects or data processing functions that may be specified by the test requirements and/or system modules.

3. Run-Time Operation

We will now describe the modules and their interaction in a real-time data acquisition operation. It is assumed that the PC and the LCNS software have been installed, and it is also assumed that the suite's data acquisition hardware has been configured in the facility module. The description traces an example of collecting a single piece of data. It should be noted, however, that several channels of data can be acquired simultaneously.

The initial step in performing LCNS testing on a system is to load the system module from floppy disk(s), provided by the system's program manager (PM) or other responsible party as defined by the PM. In addition to the system module, the floppy disk(s) must contain any historic or baseline data, any special test requirements modules, and any graphics that have been produced by the PM. The floppy disk(s) should contain a text file, "diskfile.dat", that lists all files contained on the disk(s).

The LCNS main menu has three selections as indicated in figure 2. The database operations (option 2) were not addressed in this effort and will not be discussed further. Option 3, "Run Install," allows you to selectively install or change the PC hardware (monitors, graphics card, printers, and plotters) and/or modify directories and paths. To load a new test system, you should select option 1, "Test Operations."

After you select option 1, the test operations main menu appears on the screen (fig. 3). To load a system that has not been tested by the particular TMDE suite being used, you select option 3 and the "Test - Load 'New'" menu appears. The "Test - Load 'New'" menu prompts you for information needed to create various subdirectories for data/file storage, and to copy the files from the floppy disk(s) provided by the PM (see example in fig. 4).

Figure 2. LCNS main menu.

```
                LCNS MAIN MENU
-----------------------------------------------

               1. Test Operations

               2. Data Base Operations

               3. RUN Install

-----------------------------------------------
    Enter number of selection ?  'ESC' to QUIT
```

Figure 3. LCNS test operations main menu.

```
         LCNS TEST OPERATIONS MAIN MENU
-----------------------------------------------
               1. Start Testing

               2. Develop/Modify Test Plan

               3. Load 'NEW' Test System

               4. Facility Configurations

               5. Report Test Status

-----------------------------------------------
    Enter number of selection ?   'ESC' to leave
```

Figure 4. Example of LCNS test—load 'New' screen.

```
TEST - Load 'New'

List of files in "diskfile.dat"; Tank   .sys
                                 Data1  .bas
                                 Data2  .bas
                                 Test1  .req
                                 SideView.pic
                                 TopView .pic

Enter Directory and Path for system
hit RETURN for c:\lcns\data\ TANK  -> <return>

Enter System Module filename
(hit RETURN for 'Tank.sys') -> <return>
         .
         .
         .

         (cont'd)
```

Once the system files have been loaded from floppy disk, you should select option 2, "Develop/Modify Test Plan," from the test operations main menu. For the most part, the test plan is already defined by the system module; however, you have the ability to choose the order in which test points are to be completed. A list of all test requirements for the system is displayed and you choose which tests are to be performed first—time domain or frequency domain (fig. 5). If you choose to perform time domain testing first, the frequency domain test requirements are dropped from the PC display, and you then choose the order in which time domain test types are performed.

The test types listed are categorized by their hardware requirements rather than by MIL-STD or test requirements (e.g., current injection and free-field illumination). This categorization is preferred because any given MIL-STD module may contain requirements for several different test types, including frequency domain and time domain components. The test planning routine forces you to construct the most efficient ordering of the test plan possible, by minimizing the number of configurational changes and, therefore, minimizing down-time. When conducting the test, however, you always have the ability to dynamically change the test plan ordering.

Figure 5. Example of LCNS test—test plan screen.

```
TEST - Test Plan

        Test requirements for "TANK"

     (T)ime Domain           (F)requency Domain

  1. Current Injection 10    1. Shield Eff.   5
  2. Free-field Ill.   21    2. CW Ill.      16
  3. Mil-Std 'XYZ'      6    3. Mil-Std 'ZYX' 4
  4. Mil-Std 'PDQ'     18

  Select 'T' or 'F' for test domain to complete first
          'ESC' to leave
```

Following the ordering of test types, you choose the order in which individual test points will be completed within each test type. You then complete this selection series for the other test domain (the frequency domain in this example). The basic test plan is then complete, and you are returned to the "Test Operations" main menu.

At this point, you may choose to select option 4 "Facility Configurations," to determine whether the stored data link configurations are adequate to accommodate the testing. This examination is automatically conducted, to some extent, by the software. The software compares the descriptions of each data link configuration in the facility module to the descriptions of the system's test requirements, and warns of any deficiencies. You may configure and store the new data link configurations at this time or wait until the data link is required during testing and add the new configuration dynamically.

With the test plan complete, you may start the tests via option 1, "Start testing," from the test operations main menu. A test summary/status report of the test points completed in each test type category will appear on the screen (see example in fig. 6) upon selecting option 1. You may choose to continue with the test plan or deviate from it by changing the order in which test types are completed.

The next screen, following the acceptance of a test type, is the last screen to appear before control is handed to the data acquisition module. The "Test Type Summary/Status Report" summarizes all requirements and progress for the current test type that is being performed (see fig. 7). The report lists various information about the system and the current level of testing. This screen also displays any graphic representations of the system under test, complete with overlaid test points. A complete report of the test status for the test type currently engaged is also displayed. You may accept the computer's recommendation for the next test point (based on the test plan) or select an alternate test point and proceed with testing.

Following the selection of a test point, control is turned over to the data acquisition module. For the example of a time domain test point, the module

Figure 6. Example: test—test summary/status report.

```
      TEST - Test Summary/Status Report

        Test Status for  "TANK"

  TIME Domain

   Test Type      # Test Points  % Completed

  1. Current Injection    10         0
  2. Free-field Ill.      21         0
  3. MIL-STD 'XYZ'         6         0
  4. MIL-STD 'PDQ'        18         0

  FREQUENCY Domain

   Test Type      # Test Points  % Completed

  1. Shield Effect.        5         0
  2. CW Illum.            16         0
  3. MIL-STD 'ZYX'         4         0

  Hit RETURN to proceed with high-lighted test (plan)

  or use cursor to select alternate. 'ESC' to exit
```

```
                    TEST - Test Type Summary/Status Report

SYSTEM :      XM1                      VIEW :                 ROADSIDE
TEST TYPE :   TRANSIENT INJECTION      LAST TEST POINT :      3) TI3AS1
MIL-STD :     188-125                  STATUS :               READY-CONTINUE

SELECT TEST POINT                      COMPLETED TEST POINTS
-----------------                      ---------------------
1) TI1AA1    <-- NEXT                  6) TI1AC2
2) TI1AA2                              7) TI2AC2
4) TI1AB1                              8) TI3AC5
5) TI1AA2                              3) TI3AS1
9) TI1AC1

     Hit RETURN for next test point or enter alternate number

                                 Q TO QUIT
```

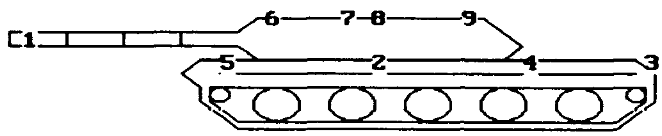


Figure 7. Example: test—test type summary/status report.

initializes itself to the time domain testing mode. The module then loads the device drivers for each type of instrument in the data links. A typical data link would consist of one or more digitizers, a probe/sensor, a fiber-optic link (FOL), and amplifiers and/or attenuators. The software can simultaneously acquire data on several data links.

The module would first initialize all the instruments in the data link(s). This initialization includes calibration-type procedures that are performed once each day, and configuring the instruments with initial settings for each data shot. For the most part, this initialization is not of concern to the operator. Depending on the type of digitizers used, initial settings include sampling rate, sweep speed, volts per division, triggering information, input impedance, etc. If there were an FOL in the data link, the software would turn on the fiber-optic transmitters and put in the proper fiber-optic attenuation, if applicable.

The software would then "arm" the digitizer(s); i.e., it would ready the digitizers for a single sweep. The digitizers would then wait in ready mode until triggered by the data signal or appropriate trigger signal. The module would then activate the source, if applicable, upon your command. Having been stored in the digitizers, the data would then be retrieved by the software. The data would then be scaled appropriately; i.e., scaled for digitizer-specific settings (volts per division, time per division, etc), and then scaled to "back out" the effects of any devices in the data link such as FOL's,

probes, attenuators, amplifiers, etc. The data would be additionally processed by any mathematical procedures defined by the system and/or test requirement modules. The processed data and any baseline data or pass/fail criteria would then be overlaid on a graphic display (see fig. 8). Except for the few essential operations you need to do, such as "telling" the software to arm for a single sweep, "fire" the source, accept or reject the data, etc, these aforementioned operations would all be performed automatically by the software.

One of the biggest problems in time domain data acquisition is getting a signal "on scale"; that is, getting the data signal amplified or attenuated to the proper level needed by the digitizers. The signal level can be estimated, either by observing previous data from similar types of measurements or by a trial and error method where several attempts are made. This problem is minimized by the baseline data and the pass/fail criteria in that they specify expected data levels for a "hard" system. The signal levels are adjusted by attenuators and amplifiers in the data link.

After the data are acquired and overlaid against the baseline data, the software may suggest sanity checks if a large discrepancy is noted—i.e., the test point appears to "fail." You may accept the data, redo the test point, and/or act on corrective actions suggested by the software. The data are then stored and you may proceed to the next test point.

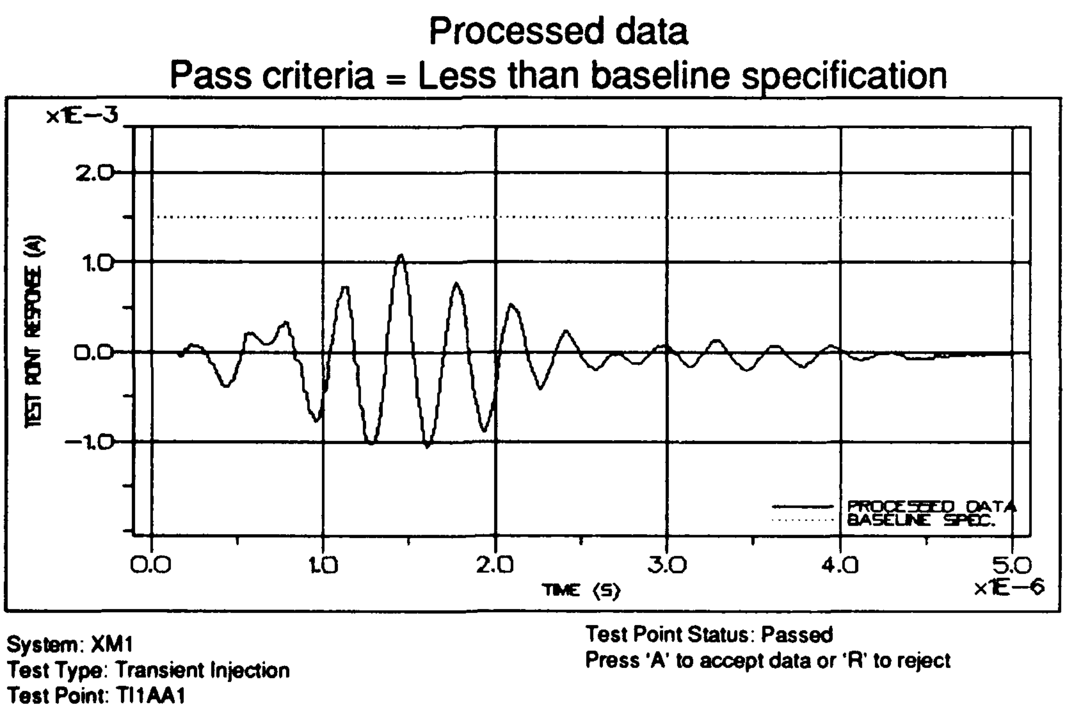


Figure 8. Example: captured data—processed.

For a frequency domain test point, the data acquisition process is the same as the time domain procedure; however, there are some significant functional differences. The frequency domain devices (network and spectrum analyzers) have the ability to "sit" on one frequency and reiteratively measure and adjust themselves to maximize the quality of the data. While this process slows the real-time data acquisition, there is no need for data-level predictions or trial-and-error data collection, as is the case for time domain testing. Additionally, since there is a time lag between each frequency point, the raw data may be displayed real-time.

Another major difference between the two test domains is the speed at which data are processed. At a minimum, each data shot is processed to remove the effects of the instruments in the data link. The calibration files for the instruments are usually stored as frequency domain transfer functions. Therefore, removing instrument effects from frequency domain data requires only simple arithmetic, whereas the same process for time domain data involves complex and time-consuming transformations and inverse transformations. It is obvious that each test domain has its pros and cons, emphasizing the need for the data acquisition module to initialize itself to the proper testing domain.

Upon completion of the current test point, control is returned to the main program shell at the same point control was given to the test module, namely the "Test Type Summary/Status Report." You can simply continue with successive test points in the test plan or continue to deviate from the original test plan. You can even back up one level to the "Test Summary/Status Report," and start a different test type even though all test points in the previous test type were not completed. In any case, the software will continually try to force you to follow the original test plan, simply tracking and skipping over test points that were completed outside the test plan order.

4. Requirements and Limitations

Some aspects of the LCNS software require responsibilities to be established for the PM and test technicians so the software can function coherently in the overall LCNS program. It is envisioned that the system's PM be ultimately responsible for the development of the system and test requirements modules for the system, although the PM may "farm out" this effort or pass it on to another party such as the TMDE PM or an LCNS PM. It is also suggested that the PM supply the graphic depictions with test overlays; however, the graphics module contains a drawing package that allows you to create graphic representations if you wish. The PM is also responsible for the maintenance of his system's LCNS database and should disseminate baseline and historic data, in the proper format, to the TMDE suites.

The LCNS TMDE suite operator is responsible for the upkeep of the facilities modules and the routine maintenance and calibration of test instrumentation. This operator is also responsible for assuring that all tests have been completed correctly, as required by the system and test requirements modules, and for delivering the new data to the PM in the proper format.

Although the LCNS has many intelligent control features to minimize data collection errors, it is certainly not foolproof. It is the objective of the LCNS software to indicate any obvious discrepancies and provide sanity checks on details that can easily be overlooked. The operators must have sufficient technical background and training to function in the defined role.

5. Future Implementations

There is a primary need for an administrative group to oversee the LCNS program. This group would be responsible for the following activities:

- developing and disseminating any changes or additions to the LCNS software, modifying the test requirement modules that accompany new MIL-STDs, or modifying existing MIL-STD modules,
- supplying engineering support for software debugging and aiding individual TMDE suites in developing test and instrument driver modules, and
- assisting the PM in developing system and test requirement modules.

Although not mentioned above, there is a concern for the security of LCNS data. LCNS data can potentially indicate vulnerabilities of military systems, therefore, precautions must be taken to secure these data. Various warnings, password protection, and encryption techniques could be incorporated into the LCNS software for secure operations. These procedures should be mandated by the LCNS administrative group.

As with all software packages, there is a cycle of test-debug-modification that will inevitably be applied to the LCNS software. The modularity of the software lends itself to a mixed language composition; therefore, it is thought that the final package will comprise several different computer languages. Each module will be written in the language that is most suited for the module's function (e.g., "C" for graphics and FORTRAN for numerical operations and data processing).

6. Summary

A comprehensive software concept for controlling LCNS data acquisition has been designed and demonstrated. The modular design of the software has intrinsic characteristics that enable it to cope with changes in instrumentation technologies, changes in MIL-STDs, and the logistical problems associated with an Army-wide LCNS program.

The development or modification of system requirements, MIL-STDs, and instrumentation are incorporated into the LCNS software through isolated changes in the appropriate modules. These changes eliminate the need to develop entirely new software systems to accommodate the new developments and modifications.

If the goal to have all Army LCNS TMDE test suites operating under this software is achieved, then many of the ambiguities in performing and interpreting LCNS tests will be eliminated. With all test suites performing the same tests, in the same manner, all LCNS data will be either equally valid or equally invalid. Even if one assumes the worst (all the LCNS is invalid), there is consistency, and corrective actions may be applied globally to the data. Furthermore, there will no longer be the potential for one test engineer to interpret a MIL-STD procedure differently from another test engineer.*

All LCNS data will be collected and transferred in a common data format, which greatly enhances the manageability of a system's LCNS program. Since this common format applies to all Army systems, an Army-wide LCNS database will provide a complete and comprehensive evaluation of the LCNS program itself as well as the LCNS of the entire Army inventory. Similarly, the Army will experience accelerated corrective and maintenance processes that ensure the survivability of the Army.

Once the LCNS software has been fully implemented, there is significant potential for cost savings. Any changes or upgrades to the LCNS software would be performed by one command and distributed throughout the Army's TMDE network. There should not be a waste of funds as a result of duplication of efforts. Any individual TMDE suite may apply more resources towards advanced technology instrumentation without budgetary concern for software designs which normally accompany a test suite upgrade.

Finally, it must be emphasized that the LCNS software can potentially be applied to any test scenario. Specific modules may be developed to satisfy specific applications, or the software can function in a generic test role to accommodate all types of testing. The strength of the software, however, lies in production-type test operations. The software has the potential to meet changing needs in instrumentation and test requirements for many years.

Some MIL-STDs are defined rather loosely and permit wide excursions within defined bounds.

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